REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
2006

2. REPORT TYPE
Journal Article Preprint

3. DATES COVERED *(From - To)*
2004 - 2005

4. TITLE AND SUBTITLE
Hall mobility of amorphous $Ge_2Sb_2Te_5$ (PREPRINT)

5a. CONTRACT NUMBER
FA9453-04-1-0370

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
61102F

6. AUTHOR(S)
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5d. PROJECT NUMBER
2305

5e. TASK NUMBER
RP

5f. WORK UNIT NUMBER
AA

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-VS-PS-JA-2006-1001

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited. (VS06-0027)

13. SUPPLEMENTARY NOTES
Submitted for publication in Physical Review B
Government Purpose Rights

14. ABSTRACT
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15. SUBJECT TERMS
Space Vehicles, $Ge_2Sb_2Te_5$, Electronic Transport, Electrical Conductivity, Seeback Coefficient, Hall Coefficient

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	Unlimited	4	Arthur Edwards
					19b. TELEPHONE NUMBER *(include area code)* 505-853-6042

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

Hall mobility of amorphous $Ge_2Sb_2Te_5$

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PACS numbers: 72.80.Ng, 72.20.Pa, 72.20.My

Chalcogenide glasses have attracted considerable attention because of their utility in switching devices.[1] In particular, thin films of non-crystalline $Ge_2Sb_2Te_5$ are currently used in many applications. However, the fundamental nature of the steady-state electronic transport of these covalent glasses remains unresolved. Is the intrinsic mobility of the charge carriers high ($\gg 1$ cm^2/V sec) or low ($\ll 1$ cm^2/V sec)?

Here we address steady-state electronic transport of the non-crystalline state of $Ge_2Sb_2Te_5$ films. Three-micron-thick films were deposited on water-cooled cover-glass substrates by radio-frequency sputtering from stoichiometric targets in 10 mTorr of Argon at the University of Utah. In-plane electronic transport measurements were made at the University of New Mexico. Conductivity measurements were performed with a 4-probe technique. Seebeck coefficients were measured using a pair of heaters and a differential thermocouple. Hall-effect measurements utilized the van der Pauw method.[2] Reference 3 provides details of the electrical transport measurements.

As illustrated in Fig. 1, the electrical conductivities of non-crystalline films were found to be thermally activated between room temperature and about 200 K: $\sigma = \sigma_0 \exp(-E_\sigma/k_BT)$. Each sample has an activation energy, E_σ, between 0.36 eV and 0.43 eV with a pre-exponential factor $\sigma_0 \approx 10^3$ S/cm. These observations are consistent with literature values.[4–6]

The Seebeck coefficients of these films were all large (~ 1 mV/K) and p-type. Figure 2 presents results obtained for one sample. The measurements become unreliable below 240 K. The results can be fit with the single-band semiconductor formula,

$$S = \frac{k_B}{q}\left(\frac{E_S}{k_BT} + A\right), \tag{1}$$

where k_B is the Boltzmann constant, q is the carrier's charge, and A is the heat-of-transport constant. Single-

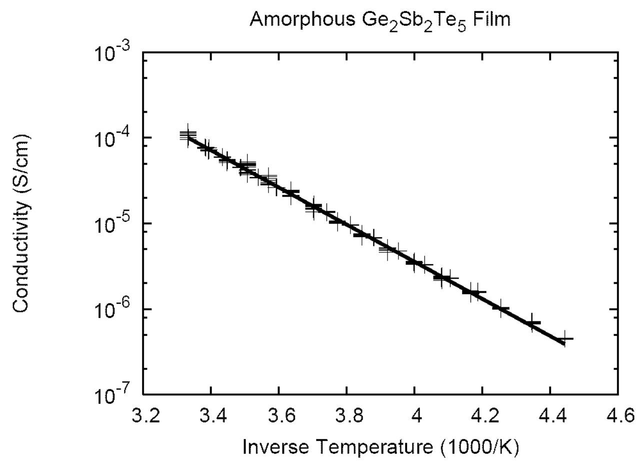

FIG. 1: Conductivity vs. inverse temperature for a typical film, the lines represents a linear least squares fits to the data. The best fit line has an activation energy of 0.43 eV.

band transport requires that $E_S \leq E_\sigma$ and $A > 0$. However, our data yields $E_S \geq E_\sigma$ and $A < 0$. Indeed, these observations are similar to those reported by Vander Plas and Bube for Ge-Te and Sb-Ge non-crystalline films.[7] We concur with Vander Plas and Bube in concluding that electrical transport in these films does not permit analysis in terms of a single type of charge carrier executing a single mode of motion.

The Hall effect remains the most promising means to probe charge carriers' intrinsic (trap-free) steady-state transport.[7] The Hall mobility measures charge carriers' deflection by a magnetic field. The Hall mobility is intrinsic in that it is unaffected by trapping since the Lorentz force only operates on moving charges.[8] For free carriers the Hall mobility equals the intrinsic (conductivity) mobility, the mobility that enters into the steady-state electrical conductivity. Trapping affects the electrical conductivity by reducing the carrier density. By con-

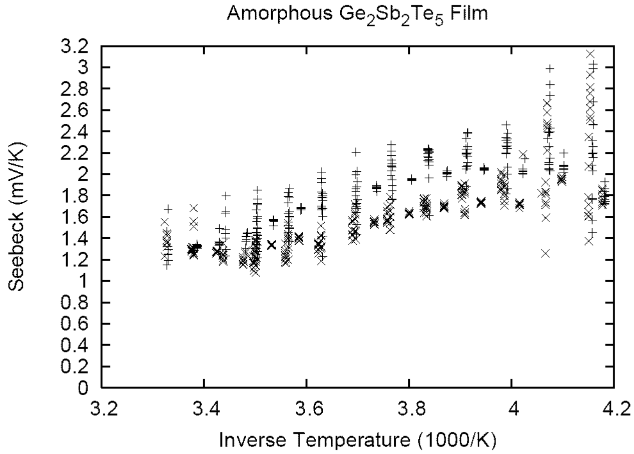

FIG. 2: Seebeck coefficient vs. temperature with datapoints denoted by 'X' symbols taken using twice the heater power of those denoted by '+' symbols.

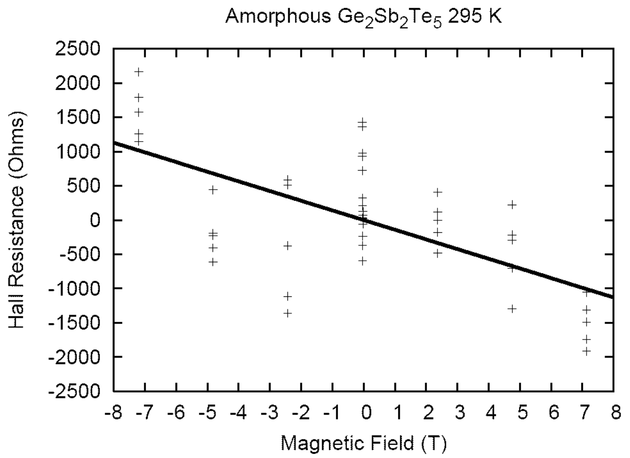

FIG. 3: Hall data at 295 K, the line represents a linear least squares fit.

trast, the relationship between the Hall mobility and the intrinsic (conductivity) mobility is more complex for carriers that move by thermally assisted hopping.[8] In particular, the Hall mobility for such carriers is frequently significantly larger and less temperature dependent than the conductivity mobility. In addition, the sign of the Hall effect for hopping-type carriers is often anomalously signed.[8–14] Then, for example, carriers that produce a p-type Seebeck effect produce an n-type Hall effect.

Hall effect measurements on low-conductivity films are difficult. Nonetheless, we made sufficiently symmetric contacts to one film to enable us to isolate the Hall signals. These small signals, presented in Figs. 3 and 4, correspond to n-type Hall mobilities of 0.07 ± 0.01 cm^2/V sec and 0.07 ± 0.02 cm^2/V sec at temperatures of 295 K and 275 K, respectively.

These measurements indicate that the Hall mobility is truly low, $\ll 1$ cm^2/V sec. Were the Hall mobility to be high, > 1 cm^2/V sec, it would have been easily detected.

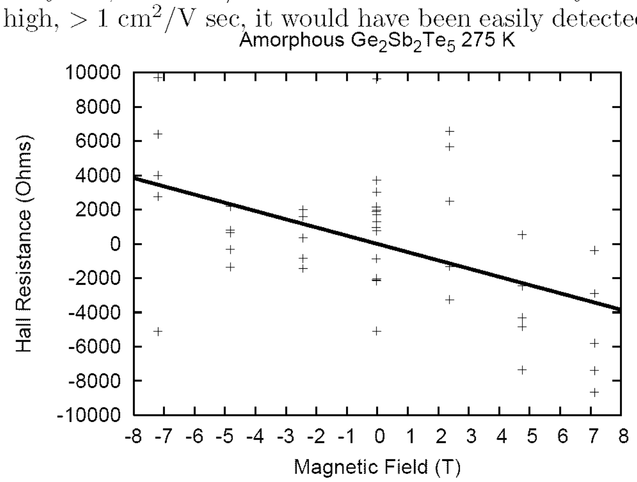

FIG. 4: Hall data at 275 K, the line represents a linear least squares fit.

Furthermore, the low mobility is unlikely to be the result of a fortuitous cancellation of contributions from electrons and holes as their relative contributions would have changed considerably with changing temperature.

Our measurement of an anomalously signed, very low Hall mobility possessing a weak temperature-dependence is consistent with the predominance of charge carriers that move by thermally assisted hopping. Indeed, these observations and conclusions are in accord with measurements and analysis of steady-state transport measurements of related chalcogenide glasses: As-Te based glasses, As_2Se_3, As_2S_3, and Sb_2Te_3.[3,9,10,15,16]

Acknowledgments

This research was performed while S. A. Baily held a National Research Council Research Associateship Award at Air Force Research Laboratory. This material is based on research sponsored by Air Force Research Laboratory under agreement number FA9453-04-1-0370. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation thereon. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of Air Force Research Laboratory or the U.S. Government.

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